Remarks

The above Amendments and these Remarks are in reply to the final Office action mailed July 12, 2006. Claims 2-5, 7-11, and 13-19 are presented herewith for consideration.

I. Status of the Claims

Currently, claims 1-19 are pending. Applicants have cancelled claims 1, 6, and 12; amended claims 2, 7, and 13; and added claims 17, 18, and 19 in this response. Claims 1-16 were finally rejected under 35 USC 103(a) as being unpatentable over Mitani et al., US Patent 5,864,161. Claims 1-16 were finally rejected under 35 USC 103(a) as being unpatentable over Freeman, US Patent No. 5,096,856 in view of Mitani et al.

II. Discussion of New Claims and Claim Amendments

New claim 17 recites a method for depositing a doped polysilicon film comprising: providing a surface; and substantially simultaneously flowing SiH_4 and BCl_3 over the surface at a temperature less than or equal to about 500 degrees Celsius under conditions that achieve an average concentration in the doped polysilicon film of between about 7×10^{20} and about 3×10^{21} boron atoms per cubic centimeter, wherein the doped polysilicon film is polycrystalline as deposited.

New claim 18 recites a method for forming an in-situ doped polysilicon film, the method comprising: providing a surface; and substantially simultaneously flowing a first source gas comprising SiH_4 and a second source gas comprising BCl_3 over the surface at a temperature less than about 500 degrees Celsius under conditions sufficient to achieve in the doped polysilicon an average concentration of between about 7×10^{20} and about 3×10^{21} boron atoms per cubic centimeter, wherein during this flowing step, polycrystalline silicon is deposited.

New claim 19 recites a method for forming an in-situ doped polysilicon film, the method comprising: providing a surface; and substantially simultaneously flowing a first source gas comprising SiH_4 and a second source gas comprising BCl_3 over the surface at a temperature less than about 500 degrees Celsius under conditions sufficient to achieve in the doped polysilicon an average concentration of between about 7×10^{20} and about 3×10^{21} boron atoms per cubic centimeter, wherein during this flowing step, polycrystalline silicon is deposited.

Support for new claims 17-19 is found throughout the application, for example in the Abstract, in paragraphs [0007], [0008], and [0023]-[0028].

III. Response to the Examiner's Response to Arguments

Applicants appreciate the Examiner's detailed Response to Arguments in the Office action of July 12, 2006, and in this section will address points raised by the Examiner.

A. The Cited References Do Not Teach the Claimed Temperatures

The Examiner asserts that the references teach deposition of polysilicon at reduced temperature, and points to col. 12 of Mitani et al. and cols. 1-2 of Freeman. At col. 12, line 11, Mitani et al. refer to a temperature of "700° C or less," while Freemen refers, at col. 2, line 13, to a temperature of 550-770 degrees C; at col. 2, line 26 to a temperature of 600 to 640 degrees C; and, at lines 61-63, to a furnace temperature set to 620 degrees C.

As described in the specification of the present application at paragraphs [0023] et seq., at about 550 degrees C, heavily doped p-type (P+) deposited silicon doped in situ is polycrystalline and conductive and has low resistivity.

As temperature falls below 550 degrees C, however, the rate of deposition of P+ polysilicon at a typical dopant concentration generally decreases and the quality of the film begins to degrade. At 500 degrees C, the film is rougher with higher resistivity. At 460 degrees C, the film is very rough and discontinuous, not suitable for uses requiring a conductive film. **It will be seen that relatively small differences in deposition temperature result in large differences in film quality.**

Original independent claims 1, 6, and 12, and new independent claims 17, 18, and 19, all recite a lower deposition temperature of 500 degrees C or below. Dependent claims 2, 9, and 15 recite narrower and lower ranges of 450-480 degrees C. The cited references refer to temperatures of 550 degrees or above, which cannot be considered to be equivalent. While it may be argued that, technically, the "700° C or less" of Freeman includes temperatures down to 0 degrees C and below, in the experience of those skilled in the art, temperatures below 550 degrees C are not practical for for this type of deposition and are not used. A deposition temperature of 500 degrees or below is neither specifically taught nor suggested in the cited references.

The Examiner goes on to ask:

> … how does the applicant's method using the same precursors and the same temperature form polysilicon? In other words, if the prior art teaches a low temperature process of forming polysilicon, it is not clear how the prior art forms amorphous silicon and the applicant forms polysilicon …

Applicants will respectfully clarify that the prior art does *not* teach a low-temperature (500 degrees C or below) method of forming polysilicon. It is not conventional to deposit silicon at the very low temperatures described in the present application and recited in the claims, as deposition rate and film quality are known to be unacceptably low at such temperatures, and neither Mitani et al. nor Freeman teaches deposition at the claimed temperatures. In the present invention the unexpected result has been found that deposition rate and film quality *improve* in this temperature range when very high levels of BCl_3 are flowed, forming a very highly doped film which is polysilicon as deposited, without the need for a subsequent anneal.

B. The References Do Not Suggest the Claimed Dopants or Dopant Concentrations

Freeman teaches deposition of a polycrystalline film formed at temperatures higher than those claimed which are doped with phosphorus. In the present independent claims the dopant, boron, is provided by BCl_3. The Examiner suggests that since boron and phosphorus are both known dopants, it would have been obvious to replace the phosphorus of Freeman with boron, and presumably a donor gas providing phosphorus (PH_3 is a typical donor gas for phosphorus) with BCl_3 as in the claims.

In his Response to Arguments, the Examiner says:

> Applicant argues that the prior art reference does not teach selecting dopant concentration which affects deposition rate, film quality, or crystallinity but that it is conventional to select dopant concentration depending on the desired concentration.
>
> The examiner agrees … **if the dopant concentration is critical to the formation of polysilicon at a low temperature and the applicant were to provide factual evidence showing same, withdrawal of the above art rejection will be considered**.

Film quality and crystallinity are affected by a variety of factors, including temperature, dopant type, and dopant concentration. Gu, US Patent Number 6,713,371, at col. 6 line 58 to col. 6 line 4 describes the affect that dopant type has on nucleation and crystallization:

> **Phosphorus atoms behave as nucleation inhibitors**, so the conditions separating formation of amorphous and of polycrystalline silicon will be changed in known ways according to the amount of dopant. The skilled practitioner will adjust temperature, pressure, and other conditions accordingly.

> The method is not relevant to conventionally produced boron-doped silicon, however. Silicon doped with boron atoms to create P-type silicon will behave differently, as the **boron atoms themselves promote nucleation. Conventionally in-situ boron-doped silicon, if deposited at the temperatures and pressures disclosed herein for deposition of undoped amorphous silicon, will be polycrystalline rather than amorphous**. (emphasis added)

Nucleation refers to formation of a nucleus about which a crystal forms. To summarize, phosphorus atoms *inhibit* crystallization, while boron atoms *promote* crystallization. Dopant type and concentration is critical to formation of polysilicon at low temperature.

Applicants also note evidence in the specification of the present application that dopant concentration is critical to formation of polysilicon at low temperature; specifically that a very high flow rate of BCl_3 during deposition is critical to formation of polysilicon at low temperature. Applicants refer to paragraphs [0027]-[0030], *inter alia*.

To paraphrase, among the disclosure in these paragraphs is the following: It has conventionally been assumed that deposition of polysilicon at very low temperature is impractical, as deposition rates drop and film quality degrades as temperature falls below 500 degrees C. In the present invention, however, it has been found when polysilicon is deposited below 500 degrees C while BCl_3 is flowed at very high concentration, the deposition rate and film quality of the polysilicon improve, making low-temperature formation of polysilicon films practical *using the donor dopant gas (BCl_3) and at the dopant concentrations described.* Substitution of different dopants, different donor gases, and use of different dopant concentrations will change the quality of the film and deposition rate.

IV. <u>35 USC 103 Rejections Over Mitani et al.</u>

Claims 1-16 were rejected under 35 USC 103(b) as being unpatentable over Mitani et al. Independent claim 1 has been cancelled and its dependent claims 2-5 have been amended to depend from new claim 17. Independent claim 6 has been cancelled and its dependent claims 7-11 have been amended to depend from new claim 18. Independent claim 12 has been cancelled and its dependent claims 13-16 have been amended to depend from new claim 19.

V. <u>35 USC 103 Rejections Over Freeman and Mitani et al.</u>

Claims 1-16 were rejected under 35 USC 103(b) as being unpatentable over Freeman in view of Mitani et al. Independent claim 1 has been cancelled and its dependent claims 2-5 have been

amended to depend from new claim 17. Independent claim 6 has been cancelled and its dependent claims 7-11 have been amended to depend from new claim 18. Independent claim 12 has been cancelled and its dependent claims 13-16 have been amended to depend from new claim 19.

VI. Conclusion

Based on the above amendments and these remarks, consideration of claims 2-5, 7-11, and 13-19 is respectfully requested.

The Examiner's prompt attention to this matter is greatly appreciated. **Should further questions remain, the Examiner is invited to contact the undersigned attorney by telephone.**

The Commissioner is authorized to charge any underpayment or credit any overpayment to Deposit Account No. 501826 for any matter in connection with this response, including any fee for extension of time, which may be required.

Respectfully submitted,

Date: October 11, 2006

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